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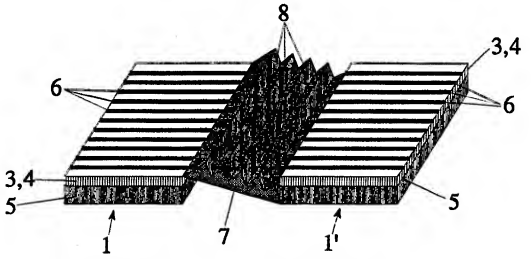

(57) Abstract

Photovoltaic solar panel comprising a plate–like first carrier provided with at least two substantially flat photovoltaic units connected in series by an electrical conductor for receiving sunlight and converting thereof into an electrical voltage difference, wherein the photovoltaic units can each be manufactured individually and have a substantially elongate form defined by two long sides and two short sides, wherein the length ratio of the long and the short sides amounts to at least 2, the units are adapted to produce a voltage difference over their long sides and the mutually facing long sides of the units lie in each case mutually adjacently along their length and the units are connected by the electrical conductor.

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SOLAR PANEL HAVING PHOTOVOLTAIC UNITS CONNECTED IN SERIES

The invention relates to a photovoltaic solar panel comprising a plate-like carrier provided with at least two substantially flat photovoltaic units connected in series by an electrical conductor for receiving sunlight and converting thereof into an electrical voltage difference.

Solar panels are known wherein the photovoltaic units are formed by solar cells which consist of wafers of silicon material and which are mutually connected in series and which are arranged at a determined mutual distance on a carrier plate. The surface area on the carrier plate between the solar cells does not of course contribute directly to the conversion of light into an electrical voltage difference and in principle has the effect of decreasing efficiency, and thereby increasing the cost price of the electricity generated with a solar panel. Reducing the non-effective surface area of the solar panels relative to the effective surface area by decreasing the distance between the solar cells causes problems in the assembly of the solar panels, while enlarging the effective surface area relative to the non-effective surface area by scaling up the solar cells results in problems in scaling-up of the wafers.

It is an object of the invention to provide a solar panel wherein the part of the surface which does not contribute towards the conversion of light into an electrical voltage difference is further reduced in size relative to the known solar panels.

This object is achieved with a solar panel of the type stated in the preamble, of which the photovoltaic units can according to the invention each be manufactured individually and have a substantially elongate form defined by two long sides and two short sides, wherein the length ratio of the long and the short sides amounts to at least 2, the units are adapted to produce a voltage difference over their long sides and the mutually facing

long sides of the units lie in each case mutually adjacently along their length, wherein the electrical conductor extends at least partially along each of the mutually facing long sides.

In a solar panel according to the invention it is possible in simple manner to increase the effective surface area relative to the non-effective surface area by enlarging the photovoltaic units in only one direction, i.e. the direction corresponding with the length direction of the units, wherein problems which generally occur during scaling-up of such units in two directions are prevented. The photovoltaic units in such a solar panel, which can each be manufactured individually, i.e. independently of each other, each form a physical unit which is connected in series to the following unit by the electrical conductor.

In an advantageous embodiment of a solar panel according to the invention the electrical conductor comprises at least one strip extending between and along the mutually facing long sides.

The length ratio of the long and the short sides preferably amounts to at least 5, more preferably at least 10 and even more preferably to at least 20.

In an embodiment the photovoltaic unit is formed by a solar cell, for instance a solar cell comprising a wafer of crystalline silicon (Si).

In an advantageous embodiment such a solar cell takes the form of a ribbon.

In yet another embodiment of a solar panel according to the invention the solar cell forming the photovoltaic unit comprises a substrate.

This substrate can be composed of for instance ceramic material, which may or may not be electrically conducting, semiconductor material, glass, metal or plastic and can comprise multiple layers, for instance for the purpose of electrical conduction, reflection of light or to enhance the nucleation of silicon.

The ceramic material for the substrate is for instance a conducting material on a basis of sintered Si to which is added for instance aluminium (Al), tin (Sn),

silicon aluminium oxynitride (SiAlON) or another material.

In another embodiment the material for the substrate is an insulating ceramic material, for instance a sintered mullite prepared according to the formula $3Al_2O_3.2SiO_2$ or a formula derived therefrom.

The metal for the substrate is for instance copper (Cu), titanium (Ti) or stainless steel (SS).

In a favourable embodiment of a solar panel with a solar cell arranged on a substrate, the substrate takes the form of an elongate strip. Elongate strips or bands of for instance stainless steel can be manufactured in great lengths, for instance about 300 m, and can be processed in simple manner into photovoltaic units for a solar panel according to the invention.

The material of the at least one solar cell on the substrate, i.e. of the active part on this plate, can comprise any suitable solar cell material and is selected for instance from one or more of the materials amorphous silicon (a-Si), alloys based on a-Si, such as for instance hydrogenated amorphous silicon (a-Si:H) or amorphous silicon alloyed with germanium (a-Si:Ge), copper indium diselenide (CIS), compounds based on CIS, copper indium sulphide, compounds based on copper indium sulphide, cadmium telluride (CdTe) and nanocrystalline titanium dioxide (nc-TiO_2).

The alloys based on a-Si comprise for instance one of the materials hydrogenated amorphous silicon (a-Si:H) or amorphous silicon alloyed with germanium (a-Si:Ge).

In yet another embodiment the at least one solar cell forming the photovoltaic unit is formed by a stack of at least two solar cells connected in series (a stack of two solar cells is designated a tandem, a stack of three solar cells is designated a cell of the triple junction type).

In an advantageous embodiment the at least one solar cell comprises a layer of thin-film crystalline silicon (f-Si). It has been found that the material f-Si is particularly suitable for allowing growth in one determined direction so that it is possible to make available

long, narrow solar cells in inexpensive and relatively simple manner.

The electrical conductor in a solar panel according to the invention comprises for instance a metal strip, a strip of semiconductor material, a strip of conducting polymer material or a strip of polymer material provided with a conducting layer, and is for instance provided with a directly or diffusely reflecting surface.

In an advantageous embodiment of a solar panel according to the invention the electrical conductor has a zigzag profile in vertical cross-section for reflecting light incident thereon to one of the photovoltaic units.

The invention will be elucidated hereinbelow on the basis of embodiments with reference to the annexed drawings.

In the drawings:

Fig. 1 shows a detail of a first embodiment of a solar panel according to the invention in perspective view,

Fig. 2 shows a detail of a second embodiment of a solar panel according to the invention in perspective view,

Fig. 3-5 show in cross-section a detail of a third embodiment of a solar panel according to the invention,

Fig. 6 shows in top view a first configuration of a solar panel in accordance with any of the embodiments of fig. 1-5,

Fig. 7 shows in top view a second configuration of a solar panel in accordance with any of the embodiments of fig. 1-5,

Fig. 8 shows in top view a solar panel according to the invention assembled from two solar cells with a multilayer structure,

Fig. 9 shows a detail of a vertical lengthwise section through one of the solar cells of fig. 8,

Fig. 10 shows in top view a solar panel according to the invention assembled from two solar cells of the type with an "interdigitated grid",

Fig. 11 shows a detail of a vertical lengthwise section through one of the solar cells of fig. 10,

Fig. 12 shows in bottom view a solar panel according to the invention assembled from two solar cells of the wafer or ribbon type with an EWT structure ("emitter wrap through"), and

Fig. 13 shows a detail of a vertical lengthwise section through one of the solar cells of fig. 12.

Corresponding components in the figures will be designated in each case with the same reference numerals.

Fig. 1 shows a detail of a first embodiment of a solar panel according to the invention with two elongate photovoltaic units 1, 1', each with a width of 5 cm and a length of 1 m, the mutually facing long sides of which lie mutually adjacently along their length and which units are connected over the whole length of 1 m by a strip-like electrical conductor 2. Each unit 1, 1' is constructed from a thin film of Si 3, 4 with a thickness of about 30 μm which is deposited on an electrically conducting substrate 5 with a thickness of about 480 μm. The thin film of Si consists of a layer 3 of n-Si with a thickness of about 0.5 μm and a layer 5 of p-Si with a thickness of about 29.5 μm. Units 1, 1' are provided on their top side with a metallization pattern consisting of parallel conducting strips 6 over the width in order to improve transport of charge carriers generated under the influence of sunlight. In the example of fig. 1, the strips 6 of the left-hand unit 1 are electrically connected to the (electrically conducting) underside of the right-hand unit 1'.

Fig. 2 shows a detail of a second embodiment of a solar panel according to the invention which differs from the panel of fig. 1 in that units 1, 1' are connected by a conducting strip 7 which is provided with lengthwise V-shaped grooves 8 which reflect sunlight incident upon strip 7 to an upper plate (not shown) where the light is reflected a second time in the direction of units 1, 1'.

Fig. 3 shows a section through a detail of a third embodiment of a solar panel according to the invention which differs from the panel of fig. 2 in that the left-hand unit 1 is connected from its upper layer 3 of n-Si to the underside of substrate 5 of right-hand unit 1' by

a conducting strip 9 provided with lengthwise V-shaped grooves 8, and an insulating sub-layer 25 is provided. The sides of the Si layers 3, 4, substrate 5 and sub-layer 25 are electrically insulated from conductor strip 9 by an insulating edge 10. Photovoltaic units 1, 1' and conductors 9 are arranged against a glass plate 12 with a thickness of about 3 mm in per se known manner using a transparent adhesive layer 11 and are covered on their underside by a laminate 13-15. It is noted that the different components in fig. 3 are not shown to scale.

Fig. 4 shows a section through the layers 3, 4 (with respectively n-Si, p-Si) and layer 5 (the substrate) in a layer thickness ratio corresponding with reality, while fig. 5 shows the layer thickness ratio of the layers 3 (n-Si) and 4 (p-Si).

Fig. 6 shows in top view a first configuration of a solar panel as according to any of the embodiments of fig. 1-5 having on a sub-layer 13 a number of 36 photovoltaic units 1, the mutually facing long sides of which lie in each case mutually adjacently along their length, and which units are connected by electrical conductors 7. Units 1 and conductors 7 have dimensions of for instance 5 cm x 1 m, respectively 1 cm x 1 m, and each of the units 1 produces for instance a voltage of about 0.5 V, so that the series connection of 36 units forms a voltage source of 18 V.

Fig. 7 shows in top view a second configuration of a solar panel as according to any of the embodiments of fig. 1-5 which differs from the configuration of fig. 6 in that on a sub-layer 13 are arranged three groups, each of 12 photovoltaic units 1, the mutually facing long sides of which lie in each case mutually adjacently along their length and which units are connected by electrical conductors 7, wherein the longitudinal direction of units 1 is parallel to the long side of the panel. The thus formed three groups are connected in series by electrical conductors 16. Units 1 and conductors 7 have dimensions of for instance 5 cm x 30 cm, respectively 1 cm x 30 cm, and each of the units 1 produces for instance a voltage

of about 0.5 V, so that the series connection of 3 times 12 units forms a voltage source of 18 V.

Fig. 8 shows in top view a configuration in which two photovoltaic units 1, 1' consisting of respective Si solar cells are mutually connected by a conductor 7.

Fig. 9 shows a detail of a vertical lengthwise section through one of the solar cells 1' of fig. 8 which consists of an Si multilayer structure on a conducting substrate 5, with alternating thin-film layers 17 of n-Si which are mutually connected by cross-layers 19 of n-Si and thin-film layers 18 of p-Si which are mutually connected by cross-layers 20 of p-Si, which cross-layers 19, 20 are mutually separated in each case by a cross-layer 21 of a conducting material. The shown unit can in principle be extended in a repeating pattern in directions to the left and right in the shown position, so that an elongate unit is obtained.

Fig. 10 shows in top view a configuration in which two photovoltaic units 1, 1' consisting of respective Si solar cells of the type with "interdigitated grid" are mutually connected by a conductor 7.

Fig. 11 shows a detail of a vertical lengthwise section through one of the solar cells 1' of fig. 10 which consists of a simple Si multilayer structure as according to fig. 3-5 on a substrate 5. Units 1, 1' are provided on their top side with a metallization pattern consisting of parallel conducting strips 6 and 6' over the width, wherein strips 6 make contact with layer 3 (n-Si) and strips 6' make contact with a layer 4' (p^+-Si) deposited on layer 4 (p-Si). The shown unit can in principle also be extended in a repeating pattern in directions to the left and right in the shown position, so that an elongate unit is obtained.

Fig. 12 shows in bottom view a configuration in which two photovoltaic units 1, 1' consisting of respective Si solar cells of the wafer or ribbon type with an EWT structure ("emitter wrap through") are mutually connected by a conductor 7.

Fig. 13 shows a detail of a vertical lengthwise section through one of the solar cells 1' of fig. 12

which consists of a layer 4 (p-Si) onto which a layer 3 (n-Si) is deposited on the top and bottom. Units 1, 1' are provided on their underside with a metallization pattern consisting of parallel conducting strips 6 and 6' over the width, wherein strips 6 make contact with layers 3 (n-Si) and strips 6' make contact with a layer 4' (p^+-Si) deposited on layer 4 (p-Si). The shown unit can in principle also be extended in a repeating pattern in directions to the left and right in the shown position, so that an elongate unit is obtained.

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CLAIMS

1. Photovoltaic solar panel comprising a plate-like carrier provided with at least two substantially flat photovoltaic units connected in series by an electrical conductor for receiving sunlight and converting thereof into an electrical voltage difference, **characterized in that** the photovoltaic units can each be manufactured individually and have a substantially elongate form defined by two long sides and two short sides, wherein the length ratio of the long and the short sides amounts to at least 2, the units are adapted to produce a voltage difference over their long sides and the mutually facing long sides of the units lie in each case mutually adjacently along their length, wherein the electrical conductor extends at least partially along each of the mutually facing long sides.

2. Solar panel as claimed in claim 1, **characterized in that** the electrical conductor comprises at least one strip extending between and along the mutually facing long sides.

3. Solar panel as claimed in claim 1 or 2, **characterized in that** the length ratio amounts to at least 5.

4. Solar panel as claimed in claim 3, **characterized in that** the length ratio amounts to at least 10.

5. Solar panel as claimed in claim 4, **characterized in that** the length ratio amounts to at least 20.

6. Solar panel as claimed in any of the claims 1-5, **characterized in that** the photovoltaic unit is formed by a solar cell.

7. Solar panel as claimed in claim 6, **characterized in that** the solar cell comprises a wafer of crystalline silicon (Si).

8. Solar panel as claimed in claim 6 or 7, **characterized in that** the solar cell takes the form of a ribbon.

9. Solar panel as claimed in claim 6, **characterized in that** the solar cell comprises a substrate.

10. Solar panel as claimed in claim 9, **characterized in that** the substrate is composed of at least two layers.

11. Solar panel as claimed in claim 9 or 10, **characterized in that** the material of the substrate respectively of the layers thereof is selected from any of the materials glass, metal, plastic, semiconductor material and ceramic material.

12. Solar panel as claimed in claim 11, **characterized in that** the ceramic material is a conducting material on a basis of sintered Si.

13. Solar panel as claimed in claim 9, **characterized in that** the substrate takes the form of an elongate strip.

14. Solar panel as claimed in claim 9, **characterized in that** the material of the at least one solar cell is selected from one or more of the materials amorphous silicon (a-Si), alloys based on a-Si, copper indium diselenide (CIS), compounds based on CIS, copper indium sulphide, compounds based on copper indium sulphide, cadmium telluride (CdTe) and nanocrystalline titanium dioxide (nc-TiO_2).

15. Solar panel as claimed in claim 14, **characterized in that** alloys based on a-Si contain one of the materials hydrogenated amorphous silicon (a-Si:H) or amorphous silicon alloyed with germanium (a-Si:Ge).

16. Solar panel as claimed in claim 9, **characterized in that** the at least one solar cell is formed by a stack of at least two solar cells connected in series.

17. Solar panel as claimed in claim 9, **characterized in that** the at least one solar cell comprises a layer of thin-film crystalline silicon (f-Si).

18. Solar panel as claimed in any of the claims 1-17, **characterized in that** the electrical conductor comprises a metal strip.

19. Solar panel as claimed in any of the claims 1-17, **characterized in that** the electrical conductor comprises a strip of semiconductor material.

20. Solar panel as claimed in any of the claims 1-17, **characterized in that** the electrical conductor comprises a strip of conducting polymer material.

21. Solar panel as claimed in any of the claims 1-17, **characterized in that** the electrical conductor comprises a strip of polymer material provided with a conducting layer.

22. Solar panel as claimed in any of the foregoing claims, **characterized in that** the electrical conductor is provided with a reflecting surface.

23. Solar panel as claimed in any of the foregoing claims, **characterized in that** the electrical conductor has a zigzag profile in vertical cross-section for reflecting light incident thereon to one of the photovoltaic units.

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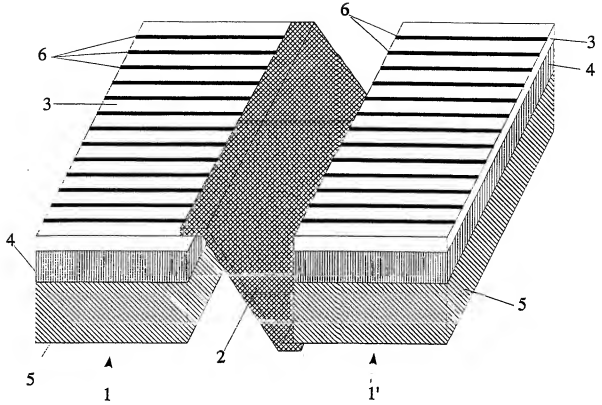

Fig. 1

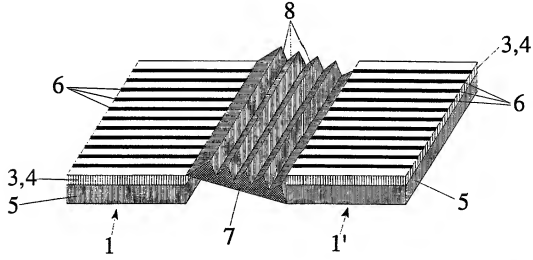

Fig. 2

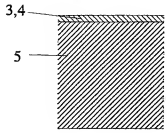

Fig. 4

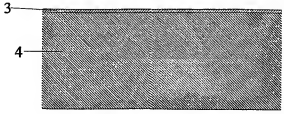

Fig. 5

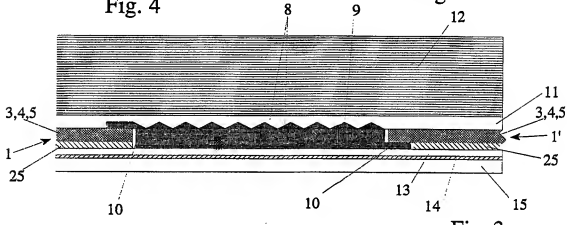

Fig. 3

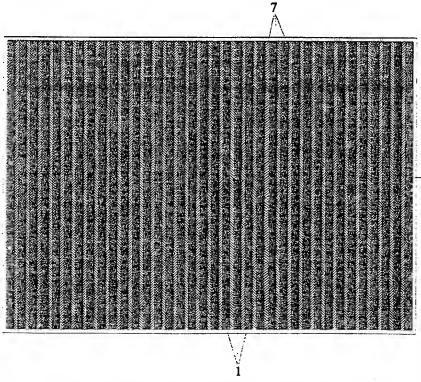

Fig. 6

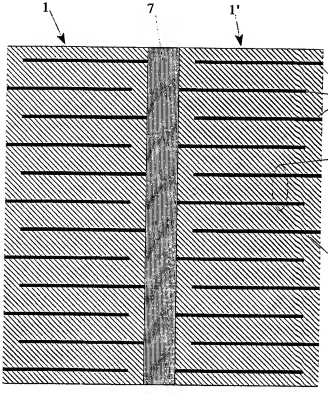

Fig. 8

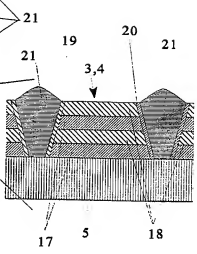

Fig. 9

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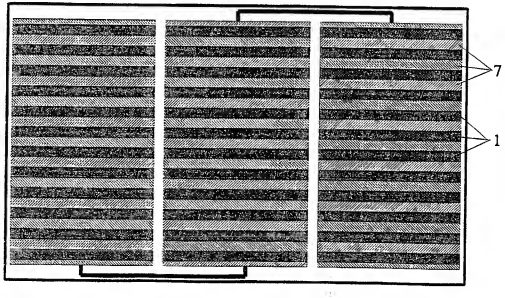

Fig. 7

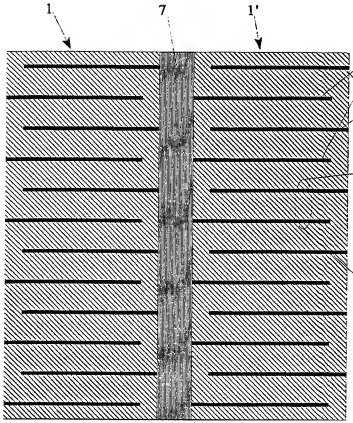

Fig. 10

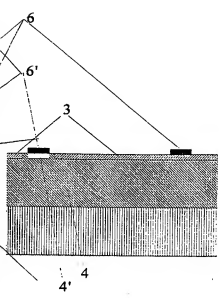

Fig. 11

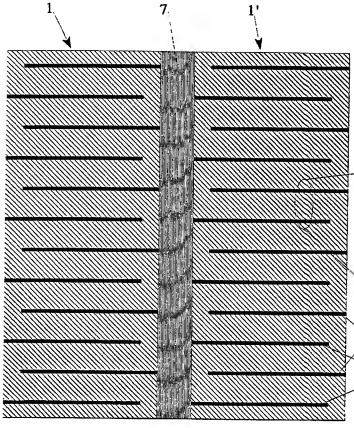

Fig. 12

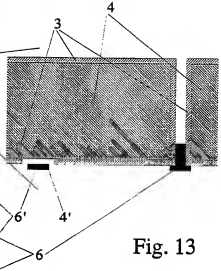

Fig. 13

INTERNATIONAL SEARCH REPORT

International Application No
PCT/NL 98/00230

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H01L31/042 H01L31/05

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 504 648 A (CANON KK) 23 September 1992 see the whole document ---	1-7, 9-11, 14-18
X	DOMINGUEZ R ET AL: "LIGHTWEIGHT, LOW COST, THIN SILICON CELL ARRAYS" 2 October 1989 , EUROPEAN SPACE POWER, MADRID, OCT. 2 - 6, 1989, VOL. 2, PAGE(S) 795 - 800 , LANDEAU J XP000173869 see page 795 - page 797; figures 2,3 --- -/--	1,2,6,7, 9,11,17, 18

[X] Further documents are listed in the continuation of box C.

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Date of the actual completion of the international search	Date of mailing of the international search report
31 July 1998	10/08/1998

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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